

9-1-2010

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## Recommended Citation

Kundart, J., Tai, YC., Hayes, JR., Sheedy, J. (2010). Word Recognition and the Accommodative Response to Desktop Versus Handheld Video Displays (Handheld Study #2). *Interface: The Journal of Education, Community and Values* 10(7). Available <http://bcis.pacificu.edu/journal/article.php?id=713>

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# Word Recognition and the Accommodative Response to Desktop Versus Handheld Video Displays (Handheld Study #2)

## **Description**

This article examines the difference, if any, in text legibility and the accommodative (focusing) response between hard copy, an LCD desktop monitor, and handheld video displays, and how it affects users' accommodative responses.

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# Word Recognition and the Accommodative Response to Desktop Versus Handheld Video Displays (Handheld Study #2)

Posted on **September 1, 2010** by **Admin**

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*Pacific University College of Optometry*

## Purpose

To determine the difference, if any, in text legibility and the accommodative (focusing) response between hard copy, an LCD desktop monitor, and handheld video displays, and how it affects users' accommodative responses.

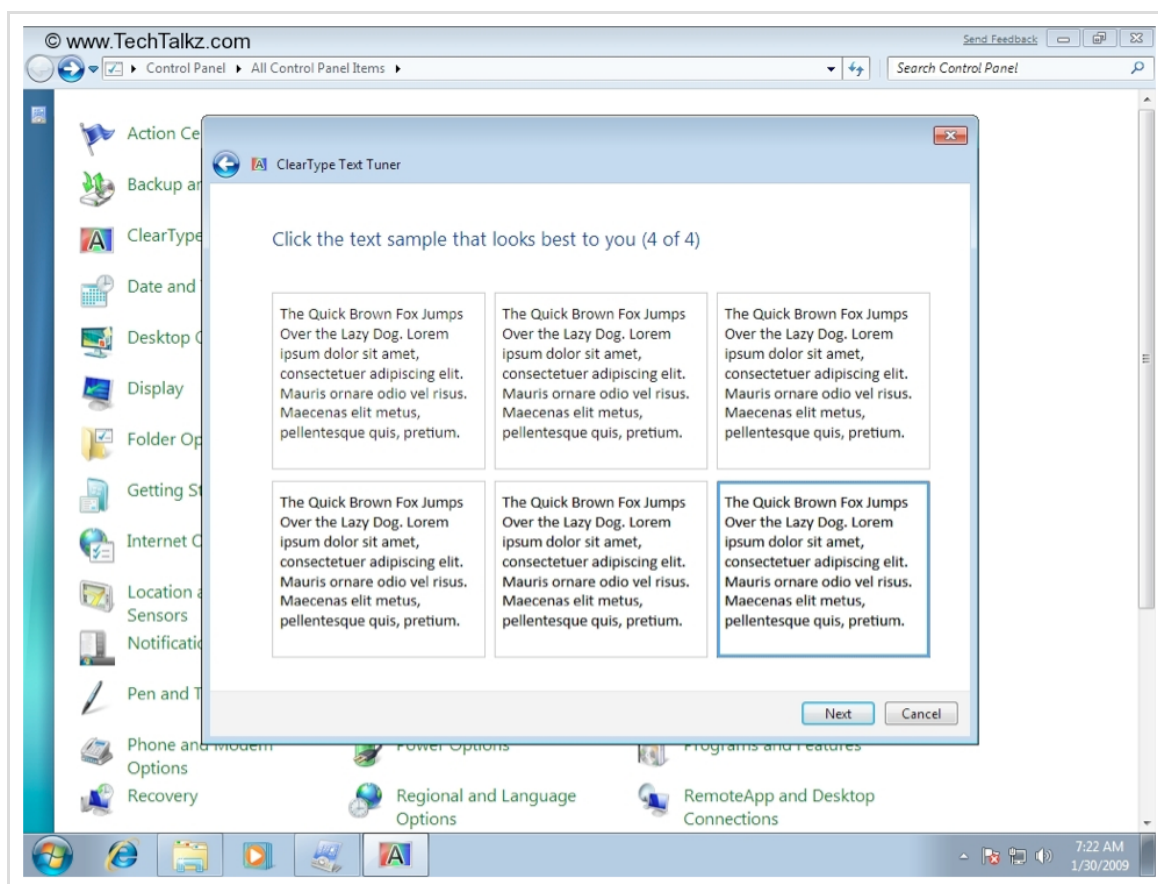
## Introduction

As much as many of us relish living in the Information Age despite difficulties with ergonomics and comfort. Both recreational computer users and those for whom it is an occupational necessity can suffer from ergonomic difficulties [1] [2].

Many users report greater comfort reading with hard copy or on a handheld device than on a desktop computer monitor [3]. One reason might be because hard copy and handheld text resolution is typically higher than inexpensive desktop monitors, despite their often smaller display size. Paradoxically, this greater comfort is despite very close working distances typically used with handheld devices [4].

In this study, both text legibility and accommodative responses were measured on desktop and handheld displays, as well as hard copy, to test the hypothesis that the higher the text resolution, the fewer the symptoms [5].

Comparing the desktop and handheld video displays, both are capable of displaying subpixel rendering known as ClearType. However, there is typically a difference in display resolution. For instance, the resolution of a typical 15" LCD desktop monitor is 120 dpi, while the resolution of a 2.5" handheld display is 140 dpi. Laser-printed hardcopy has the best letter rendering, but of course, no ClearType. See Figure 1.



**Figure 1:** ClearType Text Tuner as seen on a Windows PC

The font size in Windows Mobile does not correspond exactly with a desktop display or hard copy. In general, the font size needs to be one or two points smaller on the desktop to match the handheld display in linear size. In this study, we were careful to match these linear sizes with and without ClearType.

## Method

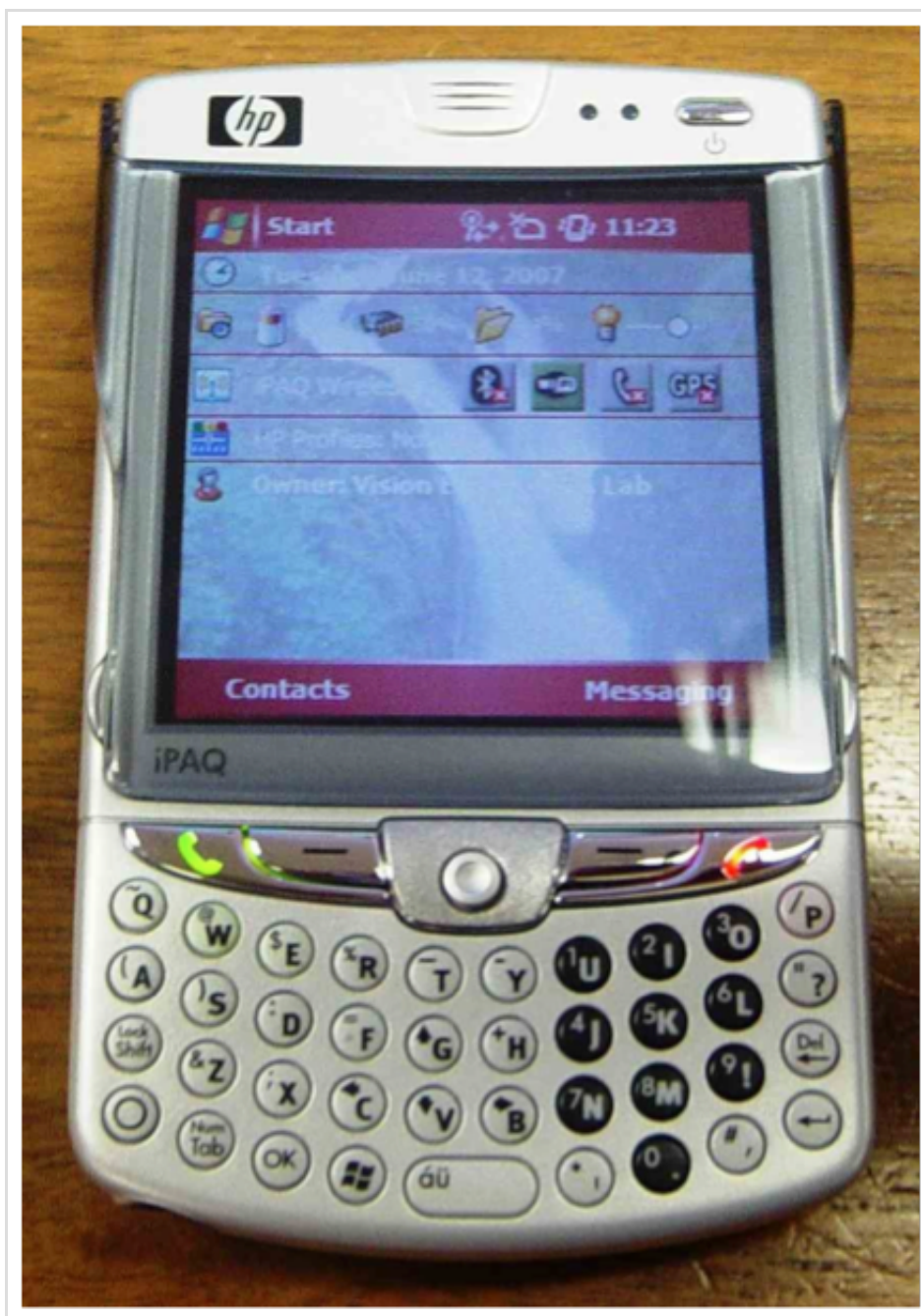
### Participants

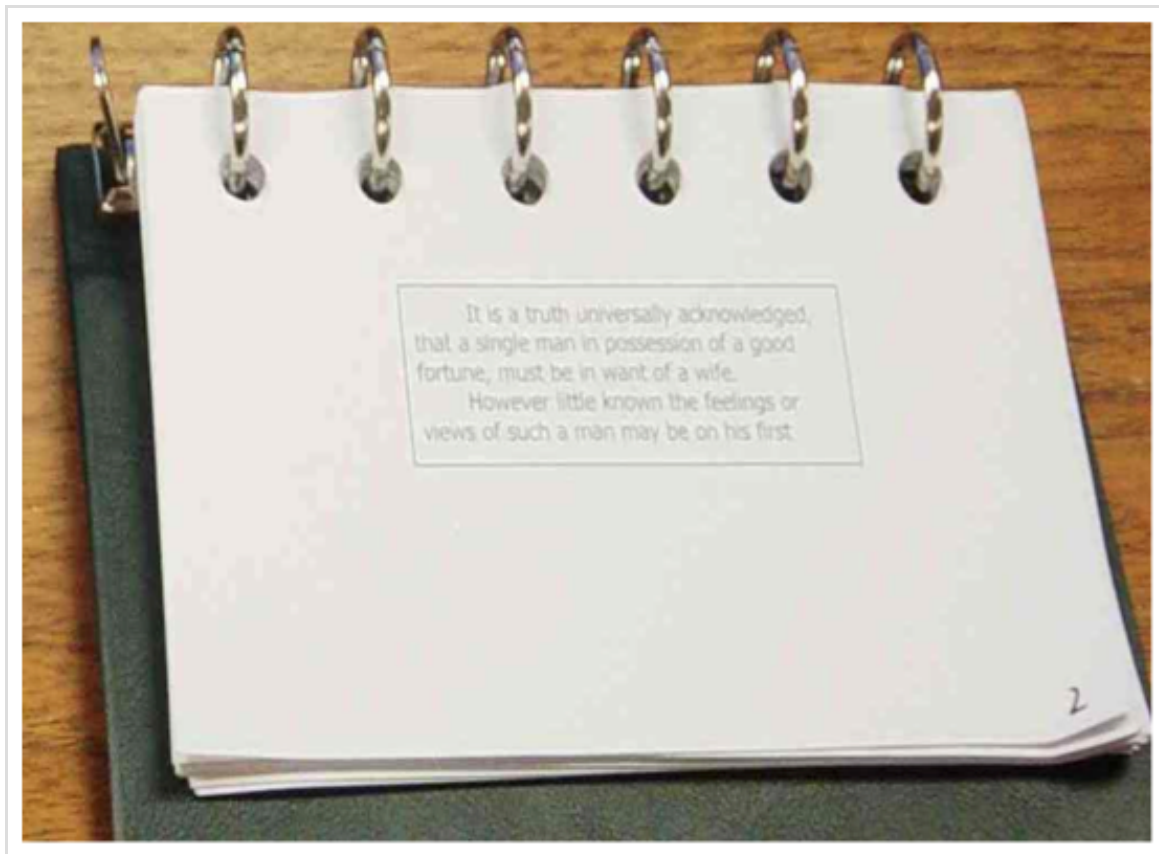
37 participants, all younger than age 40 (and therefore not in need of bifocals), completed the study. All wore the proper spectacle or contact lens prescriptions to correct them to 20/20 vision at distance, as applicable. Participants were recruited through a website following IRB and

HIPAA privacy protocols.

### Equipment

Text was displayed on a 15" desktop LCD monitor (120 dpi), a 2.5" HP iPAQ smartphone (left) (140 dpi), or hard copy (right) (printed from a 1200 dpi laser printer). Both video displays were capable of displaying ClearType rendered text. Tahoma font was used for presentation as constrained by the smartphone we used. See Figure 2.





**Figure 2:** HP iPAQ smartphone and hard copy text used

### Tasks

Participants were asked to perform two tasks: *Text legibility* and *Accommodation in reading*. Each participant performed all conditions.

In *Text legibility* task, they were asked to read aloud a row of five high frequency words of 5 or 6 letters from a designated distance. The words were displayed on hard copy, desktop monitor or handheld display at various font sizes. After each attempt, the participant was asked to back up to a distance that would increase acuity demand by logarithmic steps and repeat the process until words could be correctly recognized, as reported to the experimenter.

Participants completed nine short readings and had their accommodative response (focusing) measured while reading. All participants completed all conditions in randomized order using the Latin Square technique.

For each task, participants were asked to silently read text presented on hard copy, a desktop monitor and a smartphone display while their pupil size and accommodation were monitored with Grand-Seiko auto-refractor. See Figure 3.





**Figure 3:** Grand Seiko WAM-5500 Open-Field Autorefractor, used to measure pupil size and focusing effort exerted by the eyes at 5 times/sec

There were nine experimental conditions used for this study, and each participant was exposed to all nine of these conditions for five minutes each. Therefore, 45 minutes of raw data were gathered, each consisting of many data points. This is because our autorefractor sampled both accommodation and pupil size up to five times a second for up to 45 minutes of reading per subject, as follows:

**Condition #1:** LCD desktop monitor with font size matched to 9-pt text on smartphone, with ClearType

**Condition #2:** LCD desktop monitor with 9-pt Tahoma without ClearType

**Condition #3:** LCD desktop monitor with 9-pt Tahoma font with ClearType

**Condition #4:** Smartphone using 9-pt Tahoma without ClearType

**Condition #5 (control condition):** Smart phone using 9-pt Tahoma and ClearType

**Condition #6:** Smartphone using 12-pt Tahoma without ClearType

**Condition #7:** Smartphone using 12-pt Tahoma with ClearType

**Condition #8:** Hard copy with font size matched to 9-pt text on smartphone

**Condition #9:** Hard copy with tear-down pages and 9-pt Tahoma font

During each condition, participants were seated behind the Grand Seiko WAM-5500 open-field autorefractor for accommodative measurements. The participants read from one of several continuous text stories for 5 minutes each.

All participants were given a symptom survey after each reading condition and asked to rate their experience. Twelve questions addressed reading problems. See Appendix for an example of this survey.

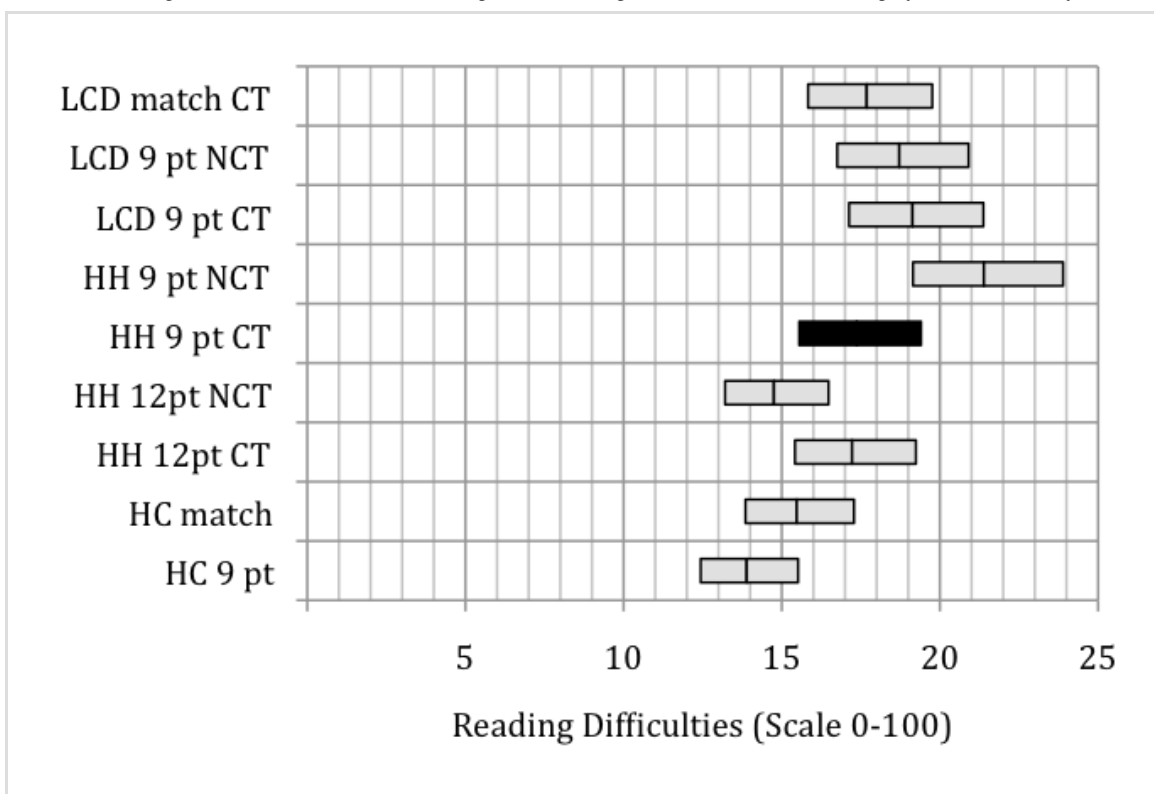
## Statistical Methods

Conditions were compared with mixed model analysis of variance. Individual paired comparisons were illustrated with confidence intervals. Non-overlapping 84% confidence intervals reveal statistically significant differences at an unadjusted  $p < 0.05$  [1]. Symptoms questions log transformed and combined into three pre-defined scales for internal (3 questions), external (4 questions), and reading problems (12 questions) using principal component analysis separately on each set of questions. Factor scores were constructed with an Anderson Rubin transformation. The confidence intervals were geometrically transformed back to the original 100 point scale for graphing [6].

## Results

Differences of text legibility were significant ( $F = 9.9$  (df 8,312),  $p < 0.001$ ). The control handheld condition (HH 9 pt CT) was equal in legibility to all other handheld conditions and significantly poorer than non-handheld conditions. The handheld 12-point ClearType was more legible than handheld 12-point non-ClearType on video displays. There were no differences between the LCD monitor and hard copy. See Figure 4.

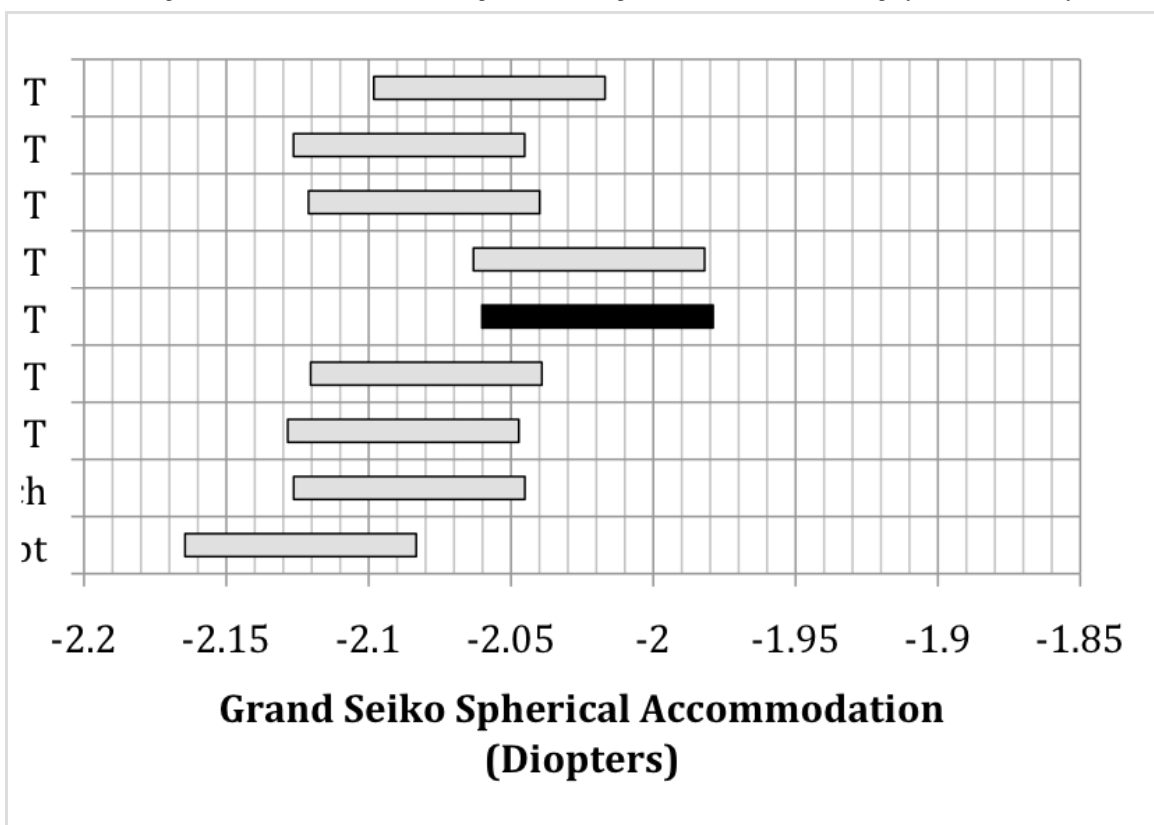




**Figure 4.** Legibility across conditions. LogMAR stands for the logarithm of the minimum angle of resolution, with 0.1 representing 20/20. Bars represent 84% confidence intervals around means. The SEM for the confidence interval was derived from the standard error of differences used in the paired comparisons. Non-overlapping confidence intervals are significant at  $p < 0.05$ , unadjusted for multiple comparisons. The black bar represents the control condition.

#### Grand Seiko Real-Time Accommodation

There was no significant main effect of ( $F=1.32$  (df 8,304),  $p=0.23$ ). Namely, focusing effort was the same with hard copy, desktop and smartphone video displays. See Figure 5.



**Figure 5:**Accommodation (focusing) effort was not significantly different comparing all conditions except the smallest (9 pt) hard copy font. (Note the y-axis labels are cut off, but are conditions 1-9 in order). The black bar represents the control condition.

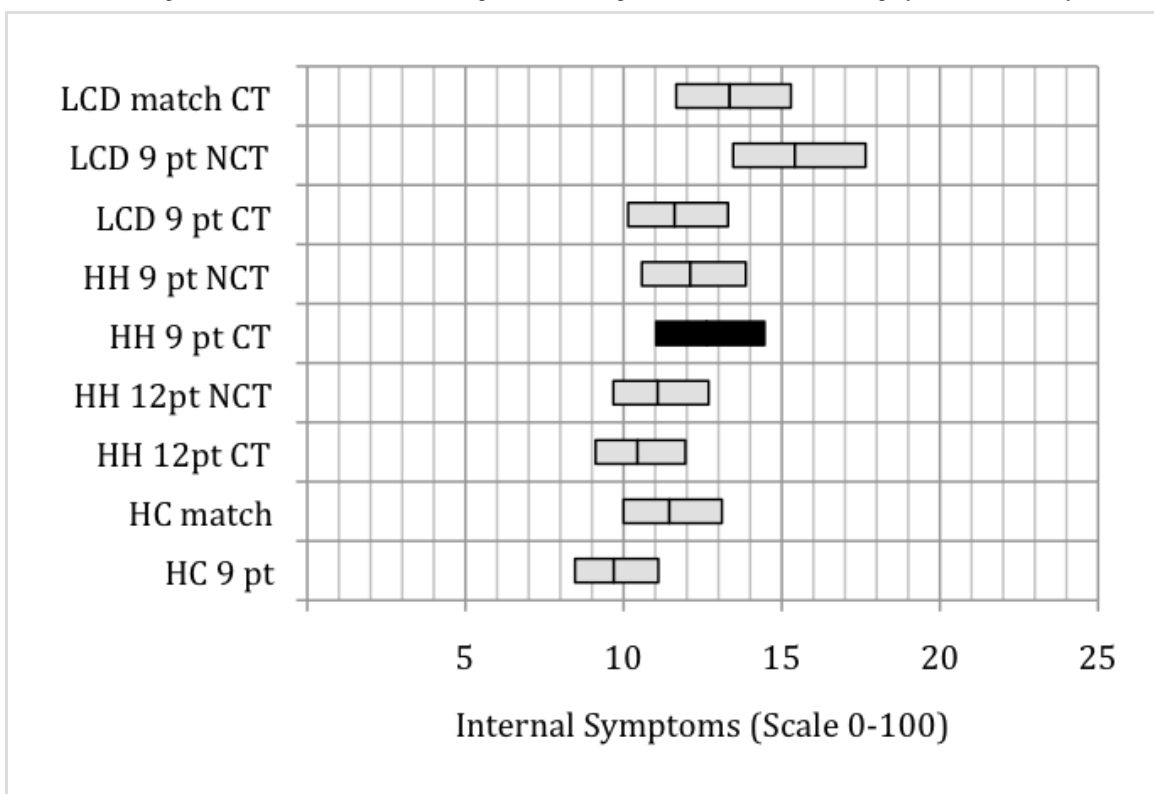
#### Relationship Between Vision Measures and Symptoms

There were only a few weak correlations between vision measures and symptom scores, as determined by survey. Survey questions and responses were divided into internal, external, and physical symptoms.

#### Internal Symptom Factors

These included survey items about sore eyes, eye ache, eye pain, headache and eyestrain.

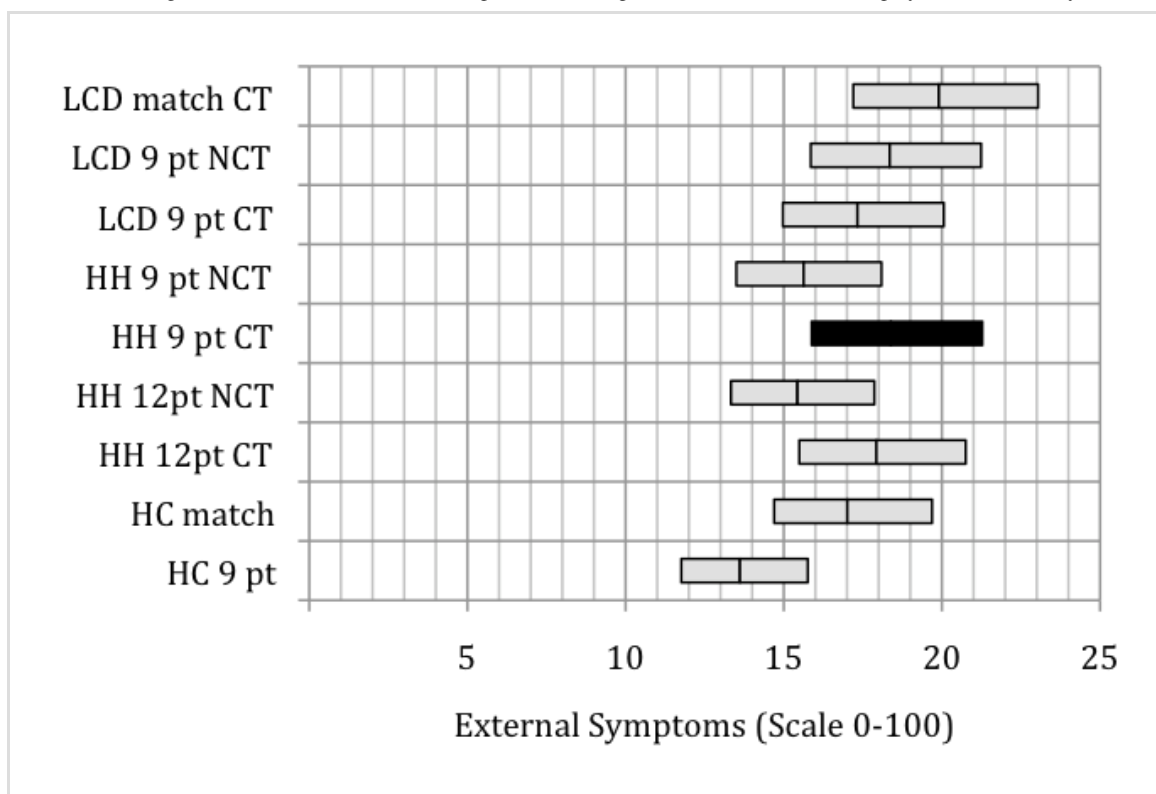
Except for comparing the smallest size font without ClearType on the smartphone vs. hard copy, there was no significant effect of internal symptoms ( $F=2.049$  (df 8,311) ,  $p=0.04$ ). See Figure 6.



Relationship between internal symptoms and display used. Note that the desktop monitor with 9 pt font caused fewer symptoms than the same size font on the LCD desktop monitor, but only without ClearType. The black bar represents the control condition.

#### External Symptom Factors

External symptoms included eye irritation, burning, tired eyes, dry eyes, and tearing. There was no significant effect of external symptoms ( $F=1.23$  (df 8,312),  $p=0.28$ ). However, the hard copy text with the smallest font showed fewer symptoms than the most of the electronic displays, regardless of font size. See Figure 7.

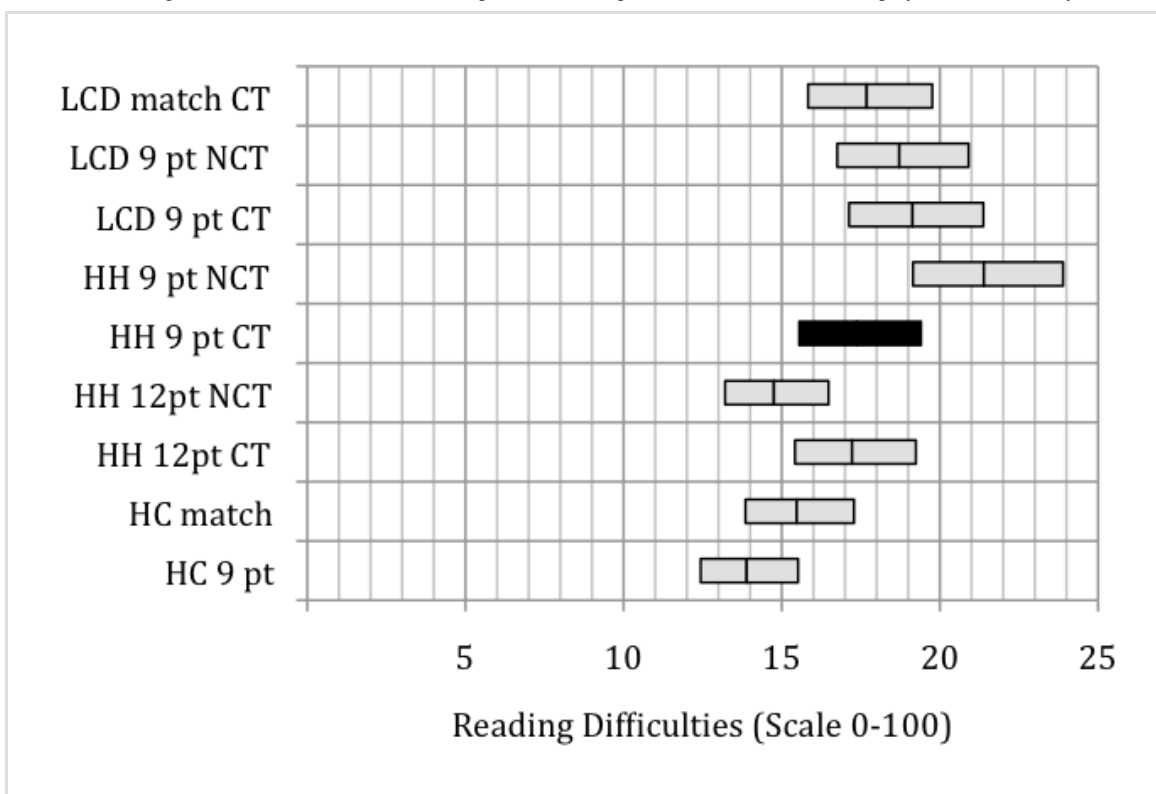


Relationship between external symptoms and display used. Note that the hard copy text with 9 pt font caused fewer symptoms than most of the electronic display conditions. The black bar represents the control condition.

There was no statistically significant effect of physical symptoms, such as neck pain ( $F=1.56$ ,  $p=0.137$ ).

#### Reading Problems

Twelve questions addressed reading problems. There was a significant main effect of condition ( $F=3.3$  (df 8, 304),  $p=0.001$ ). Comprehension accuracy had no effect. In other words, the three different displays (hard copy, desktop and smartphone video displays) were all equally easy to see. The exception was at the smallest font size, judging from the frequency of symptoms surveyed, the hard copy was still preferred. See Figure 8.



Relationship between reading problems and display used. Note that the hard copy with 9 pt font caused fewer symptoms than the same size font on the smartphone, but only without ClearType. The black bar represents the control condition.

#### Pupil Size

The Grand Seiko WAM-5500 autorefractor measures pupil size as well as accommodation. The iris pupil changes size in response to two primary factors: lighting changes and accommodative changes. See Figure 9.

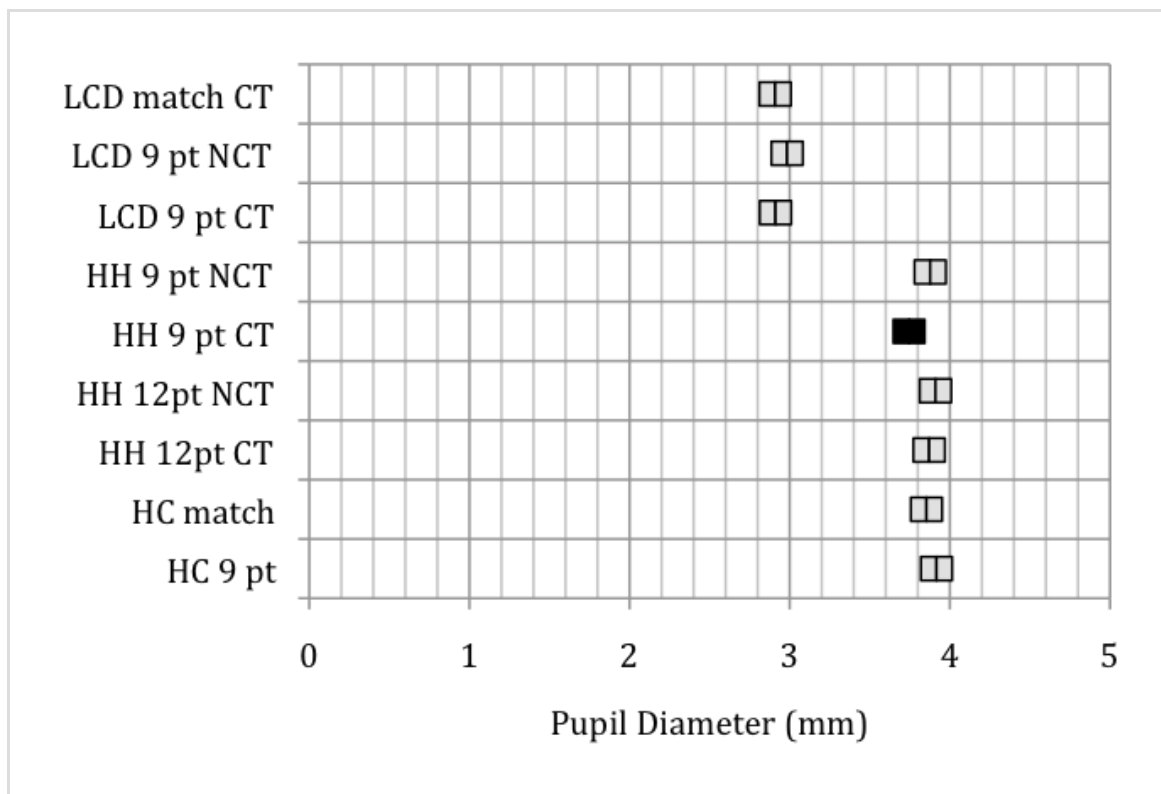


**Figure 9:** Pupil size measurement with the Grand Seiko WAM-5500 was possible up to five times/sec

Pupil size was not associated with accommodation ( $F=2.29$  df 1,340,  $p=.13$ ; pseudo  $R^2=.004$ ). The pseudo  $R^2$  was computed using the mixed model analysis taking the ratio of predicted value variance to total variance.

There was a significant effect of pupil size without controlling for any other variables ( $F=53.37$ ; DF 8,304  $p < 0.001$ ), with the desktop monitor causing significantly smaller pupil size than the handheld display or hard copy. See Figure 10.





Pupil size was significantly smaller with the desktop monitor, regardless of font size. This is likely due to the increased luminance of the white background in a typical Word document, as we used. The black bar represents the control condition.

Also, pupil size was significantly smaller when looking at the desktop monitor than either the handheld or hard copy ( $F=53.370$   $p < 0.001$ ), likely due to monitor brightness when black text is displayed on a black background. While not tested, smaller pupil size generally increases depth-of-focus.

#### Other Results: Residual Refractive Error

At the beginning of each participant's study, baseline residual refractive error after corrective lenses was measured.. There was no significant relationship between accommodation and refractive error (OD  $F=1.63$   $df$  1,45,  $p=.209$ ; OS  $F=1.0$   $df$  1,43,  $p=.32$ ).

### Conclusions

Legibility is worse on the handheld display tested (HP iPAQ smartphone) than on the LCD desktop monitor tested, or hard copy. Accommodative responses were not significantly different on handheld displays versus desktop monitors and hard copy.

Internal symptom factors (sore eyes/ eye ache/ eye pain, double vision, blurred vision, headache and eyestrain) were not significantly related to accommodation. Conversely, external symptom factors (irritation, burning, tired eyes, dry eyes, tearing) were worse with desktop and handheld displays than hard copy. This result is supported by previous research [7] [8].

As accommodation relates more closely to the internal symptoms, focusing alone does not seem to explain these differences. This was borne out by the accommodative measurements made with the Grand Seiko autorefractor. Participants reporting reading problems showed insignificantly different accommodative responses.

However, one explanation as to why our participants had greater external symptoms with the desktop monitor may be that pupil size is significantly smaller in response to desktop versus handheld video displays. Smaller pupil size might cause symptoms by itself, according to the following logic:

1. 1. The pupils constrict more when using a desktop video display as compared to a handheld one, such as a smartphone, undoubtedly due to greater luminance of the standard white background on the desktop monitor
2. 2. Pupil constriction occurs to a lesser extent due to accommodation, or focusing, of the eyes
3. 3. Accommodation also triggers convergence of the eyes through the extraocular muscles
4. 4. Many vision scientists believe that overstimulation and fatigue of this so-called “near triad” of convergence, accommodation and pupillary constriction causes fatigue and eyestrain

While this study has only proven a consistent difference in the effects of handheld versus desktop video displays to be with pupil size, not accommodation, future studies should examine the last leg of the near triad, convergence.

Looking to the future, these researchers would like to discover why users seem to be more comfortable with shorter working distances when using hard copy or handheld video displays, compared to desktop computer displays. One possible reason may be that hard copy and handheld devices, like smartphones, provide proprioceptive feedback from the hand that better helps to aim the eyes than when using a desktop monitor place out of arm’s reach. Another is that handheld video display users may only be using one eye. [9]

These possibility, and others, will hopefully be addressed by another study of handheld video displays and eye teaming.

### **Acknowledgements and Financial Disclaimer:**

Funding for this study was provided by the Advanced Reading Technologies Group of Microsoft Corporation. The authors have no financial interest in Hewlett Packard or Grand Seiko corporations.

### **References**

[1] Ergonomics, part one : is the job you love a pain in the neck? / Linda Roach. EyeNet 1097-2986 2009 Jul/Aug; 13(7): 49-50.

- [2] Seven risk factors for injury, and seven solutions : ergonomics, part two / Linda Roach. EyeNet 1097-2986 2009 Sep; 13(8): 45-46,48-50.
- [3] Sheedy JE, Hayes JR, Engle J. Is all asthenopia the same? Optom Vis Sci 2003;80:732-739.
- [4] Hemphill N. Handheld device use poses more stress on eyes, body than reading printed copy. Prim Care Optom News Primary Care Optometry News 1081-6437 2008 Dec; 13(12): 5.
- [5] Vasta S. Ergonomics research aims to help reduce visual demands of computer use : studies designed to improve usability are focusing on enhancing font designs. Primary Care Optometry News 1081-6437 2008 Apr; 13(4): 24.
- [6] Payton ME, Greenstone MH, Schenker N. 2003. Overlapping confidence intervals or standard error intervals: What do they mean in terms of statistical significance? 6pp. Journal of Insect Science, 3:34, Available online: [insectscience.org/3.34](http://insectscience.org/3.34)
- [7] Anshel J. Diagnosing, treating CVS relies on good case history : basic eye care, ergonomics and optical correction are all part of an effective treatment plan for computer vision syndrome. Primary Care Optometry News 1081-6437 2007 Sep; 12(9): 14-16.
- [8] DePaolis MD. CVS requires multifaceted treatment : computer vision syndrome demands attention to ergonomics, ocular surface and vision correction / Michael D. DePaolis. Primary Care Optometry News 1081-6437 2007 Sep; 12(9): 3.
- [9] Villa JLR. Monocular impairment in video display terminal operators : a case series. J Behav Optom Journal of Behavioral Optometry 1045-8395 2006; 17(6): 143-148.

#### APPENDIX A: DIGITAL SYMPTOM SURVEY

For each of the following symptoms, choose the sensation that most closely represents the severity you experienced during reading just now.

	None	Mild	Moderate	Bad	Severe
<u>Sore eyes, painful eyes, or ache in or around eyes</u>	None	Mild	Moderate	Bad	Severe
<u>Double vision</u>	None	Mild	Moderate	Bad	Severe
<u>Blurred vision</u>	None	Mild	Moderate	Bad	Severe
<u>Headache</u>	None	Mild	Moderate	Bad	Severe
<u>Eye strain or pulling of the eye muscles</u>	None	Mild	Moderate	Bad	Severe
<u>Irritation or burning of the eyes</u>	None	Mild	Moderate	Bad	Severe
<u>Tearing, or watery eyes</u>	None	Mild	Moderate	Bad	Severe
<u>Dry eyes</u>	None	Mild	Moderate	Bad	Severe
<u>Tired eyes</u>	None	Mild	Moderate	Bad	Severe
<u>Bothered by brightness</u>	None	Mild	Moderate	Bad	Severe
<u>Bothered by glare</u>	None	Mild	Moderate	Bad	Severe

<u>Computer screen fonts look too small</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Computer screen colors are distorted</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Computer screen clarity is poor</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Desire to blink harder</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Desire to blink more often</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Difficulty concentrating on the text</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Difficulty comprehending the text</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Difficulty remembering the text</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Feeling sleepy or eyelids feel heavy</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Feeling dizzy</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Desire to move closer or further away from the screen</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>
<u>Desire to stop or take a break</u>	<u>None</u>	<u>Mild</u>	<u>Moderate</u>	<u>Bad</u>	<u>Severe</u>

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26 THOUGHTS ON “WORD RECOGNITION AND THE ACCOMMODATIVE RESPONSE TO DESKTOP VERSUS HANDHELD VIDEO DISPLAYS (HANDHELD STUDY #2)”

**Billie Yerke**

on **September 12, 2013 at 3:49 PM** said:

Good read!

**James Kundart**

on **October 8, 2013 at 9:46 PM** said:

I'm glad you enjoyed it. We have made many discoveries since. Feel free to contact me

if you'd like to learn more.

**dating**

on **January 30, 2014 at 11:35 AM** said:

you've any? Kindly enable me understand so that I may perhaps just subscribe. Thanks.  
at the same time conceive so , perfectly written post! .

**Tracee Norsaganay**

on **January 30, 2014 at 6:15 PM** said:

I think other web site proprietors should take this web site as an model, very clean and wonderful user friendly style and design, as well as the content. You are an expert in this topic!

**vitamins for weight loss**

on **January 31, 2014 at 7:43 AM** said:

With havin so much written content do you ever run into any problems of plagorism or copyright violation?

My website has a lot of completely unique content I've either authored myself or outsourced but it seems a lot of it is popping it up all over the web without my authorization. Do you know any techniques to help protect against content from being stolen? I'd certainly appreciate it.

**plotka**

on **February 1, 2014 at 1:56 AM** said:

We are a group of volunteers and beginning a brand new scheme in our community. Your web site provided us with valuable details to paintings on. You have performed an



impressive employment and our entire neighborhood can be thankful to you.

**filmy**

on **February 1, 2014 at 2:17 AM** said:

Thanks much for providing individuals with these kinds of a remarkable opportunity to read significant reviews from here. It is often so superb plus packed using a lot of fun for me personally and my office peers to visit your internet site minimum 3 times each week to discover the new issues you have. And indeed, I'm also actually satisfied as part of your astonishing tips served by you. Some 2 info in this posting are entirely the simplest we've ever had.

**Natural Cleanse**

on **February 2, 2014 at 5:49 PM** said:

great points altogether, you simply won a emblem new reader.

What would you suggest in regards to your put up that you just made some days ago? Any sure?

**nigeria**

on **February 3, 2014 at 1:38 AM** said:

Great blog correct here! Additionally your internet site loads up very fast! What host are you the usage of? Can I get your associate link on your host? I wish my site loaded up as easily as yours lol

**temat**

on **February 3, 2014 at 1:54 AM** said:

Thanks to your advice! I'll read it to understand more about Holy Cross.

**fat burning supplements**

on **February 3, 2014 at 8:11 AM** said:

Amazing! Its actually amazing paragraph, I have got much clear idea on the topic of from this piece of writing.

**Muscle Zx90**

on **February 3, 2014 at 2:51 PM** said:

I seriously love your site.. Pleasant colors & theme. Did you build this site yourself? Please reply back as I'm trying to create my own site and would love to learn where you got this from or what the theme is named.

Thanks!

**peptide skin care**

on **February 4, 2014 at 10:14 PM** said:

I'm no longer certain where you're getting your info, however good topic.

I must spend a while finding out much more or working out more.

Thank you for great info I used to be on the lookout for this information for my mission.

**Nigeria social network**

on **February 5, 2014 at 12:17 AM** said:

Take a 10-minute break during by the hour which you study. Create a schedule that one could stay with it.

**<http://garciniatotals.com/>**

on **February 5, 2014 at 10:24 AM** said:

I am really impressed with your writing skills as well as with the layout on your blog. Is this a paid theme or did you customize it yourself? Anyway keep up the excellent quality writing, it is rare to see a great blog like this one nowadays.

**Sirudang.Com**

on **February 5, 2014 at 11:41 AM** said:

Post writing is also a fun, if you be familiar with afterward you can write otherwise it is difficult to write.

**natural body cleanse**

on **February 5, 2014 at 11:51 AM** said:

Heya this is kinda of off topic but I was wondering if blogs use WYSIWYG editors or if you have to manually code with HTML.

I'm starting a blog soon but have no coding know-how so I wanted to get advice from someone with experience. Any help would be greatly appreciated!

**green Coffee Diets**

on **February 5, 2014 at 2:05 PM** said:

We're a group of volunteers and starting a brand new scheme in our community. Your web site offered us with valuable information to work on.

You've done a formidable job and our whole community can be thankful to you.

**organic goji berries**

on **February 5, 2014 at 6:24 PM** said:

Please let me know if you're looking for a article author for your weblog. You have some really great posts and I think I would be a good asset. If you ever want to take some of the load off, I'd really like to write some material for your blog in exchange for a link back to mine. Please shoot me an email if interested. Many thanks!

**herbal testosterone booster**

on **February 6, 2014 at 1:04 AM** said:

I am actually grateful to the holder of this web page who has shared this wonderful piece of writing at here.

**when to take raspberry ketones**

on **February 6, 2014 at 2:00 AM** said:

I go to see every day some blogs and blogs to read posts, however this weblog gives quality based posts.

**yesdd.co.kr**

on **February 6, 2014 at 4:06 AM** said:

Thanks for sharing such a good thinking, paragraph is pleasant, thats why i have read it entirely

**world kitchen locations**

on **February 6, 2014 at 5:18 AM** said:

Buildings will all ultimately fall to the ground. Step three: Arrive Early Show up at the meeting early and set up your equipment.

**revolynweightloss.com**

on **February 6, 2014 at 6:17 AM** said:

whoah this weblog is magnificent i really like studying your articles.

Keep up the great work! You realize, lots of people are hunting around for this information, you can help them greatly.

**best green coffee beans**

on **February 6, 2014 at 1:35 PM** said:

Hello, i think that i saw you visited my website thus i came to "return the favor".I am attempting to find things to enhance my site!! suppose its ok to use some of your ideas!!

**best anti aging supplements**

on **February 6, 2014 at 2:12 PM** said:

I have read so many articles or reviews concerning the blogger lovers however this post is in fact a nice piece of writing, keep it up.